A Brief History of USAF Applied Research Concerning Military Aviation Fatigue and Performance

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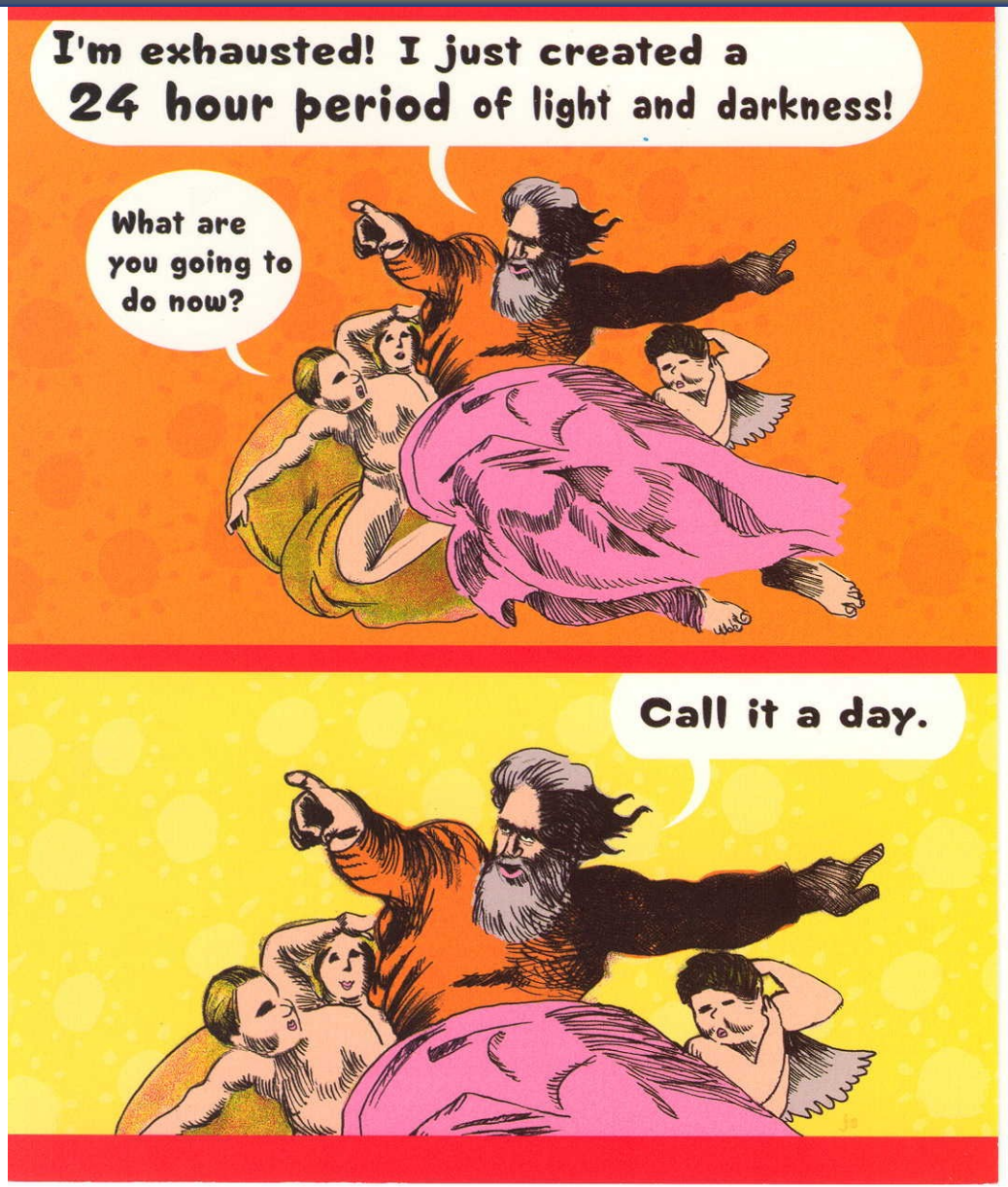
A Tireless God that Chooses to Rest

- **"We have created the heavens and the earth, and everything between them in six days, and no fatigue touched us." -- Qur'an 50:38**
- **“He will never grow tired or weary.” -- The *haftorah* to *parshat Lech Lecha* (Isaiah 40:28)**
- **“And on the seventh day God ended his work which he had made; and he rested on the seventh day from all his work which he had made.” -- Genesis 2**

A Tireless God that Chooses to Rest



God as a Source of Rest and Recovery

- **“He gives strength to the weary [*notain koach la'ya'aif*; Morning Blessings] and increases the power of the weak. Even youths grow tired and weary, and young men stumble and fall; but those who hope in the Lord will renew their strength.” -- The *haftorah* to *parshat Lech Lecha* (Isaiah 40:28)**
- **23rd Psalm: “He makes me to lie down.” “He restores my soul.”**

Resting on the Sabbath Day*

- **Exodus 20:8-11: Set aside the Sabbath as a period during which we do not labor.**
- **Karl Barth: "Do as much or as little as the day brings—the day should be free from compulsion."**
- **Four elements of quality rest: "Communion with God and family; separation of mind, body and soul from the constant tug of work and the world; restoration of mind, body and soul; and contemplation of how and where God has been at work."**
- **Activities unhurried; set no alarms; take naps; pursue hobbies**

***John Anthony Page (2002). The gift of Sabbath. *Discipleship Journal*, 127, 33-38.**

Judeo-Christian Scriptures and the Workday*

- **The sociological concept of “hurrysickness.”**
- **Symptoms: Seeing family and friends as obstacles to accomplishing work. The compulsion to accomplish.**
- **C.S. Lewis: “It comes the very moment you wake up each morning. All your wishes and hopes for the day rush at you like wild animals. And the first job each morning consists in shoving them all back; in listening to that other voice, taking that other point of view, letting that other larger, stronger, quieter life come flowing in.”**
- **Set aside some quiet time in the early morning for introspection, confession and supplication**

***Tim Muehlhoff (2002). Putting people in their place. *Discipleship Journal*, 127, 53-57.**

Islamic Scriptures and the Workday*

- **The Prophet: "Praying relieves fatigue."**
- **The Qur'an defines a daily program that includes rest and recovery through prayer.**
- **An early rising allows work to be started and completed early; prayers are repeated five times every day**
- **After morning prayer, Muslims go to work feeling "optimistic and high spirited."**
- **The next prayer comes after the fatigue induced by seven hours of work and "serves as a relaxation technique according to the teachings of Islam."**

Islamic Scriptures and the Workday*

- **Faith and hope help "reduce anxiety and tension and relieve depression."**
- **"The act of praying constitutes a vivid meditation exercise which is repeated five times daily at the acme of physical and psychological fatigue."**

***Osama Mohammad Al-Radi (1999). The Role of The Mosque in Mental Health. *Proc. 6th International Congress of WIAMH*, Tuzla, August.**

Greek Mythology and Sleep as a Passive State

- **Nothing in existence until Chaos (the abyss, a void, or a formless confusion) came into being.**
- **Out of this void came, among other things, Nyx (night), Erebus (darkness), Eros (love), and Gaea (Earth).**
- **Nyx was the mother of many, including Hypnos (sleep; the Romans' god, Somnos), Thanatos (death), Moros (doom), the Fates or Moerae, and the Oneiroi (personifications of dreams, black-winged demons).**

Greek Mythology and Sleep as a Passive State

- **Hades ruled the Underworld, through which flowed five rivers, including Lethe (forgetfulness).**
- **The shades of the dead were required to cross all five rivers before they could be judged and sent to their final place of rest.**
- **The Oneiroi lived near the entrance of the Underworld and near the river Lethe.**
- **Thus, sleep was probably associated primarily with night, death, doom, fate, and forgetfulness.**
- **Consistent with the incorrect assumption today that sleep is a passive, vegetative state.**

Shakespearean View of Sleep as Death-like

- **Macduff announces the murder of King Duncan: "Malcolm. Banquo. Awake! Shake off this downy sleep, death's counterfeit, And look on death itself."**
- **Macbeth: "Sleep that knits up the ravell'd sleeve of care, The death of each day's life, sore labour's bath"**
- **In *Measure for Measure* the Duke comforts Claudio who is to die: "The best of rest is sleep..."**

Emphases added

The Roman Army, AD 1

- **163 AD: "This great decay in military discipline Lucius took in hand as the case demanded, setting up his own energy in the service as a pattern. …*he keeps the first watch easily, for the last he is awake long beforehand* and waiting; work is more to his taste than leisure, and his leisure he misuses for work… The sleep he took was earned by toil, not wooed with silence." Marcus Cornelius Fronto. In Dave Stewart (2000), *The Roman Army: AD 163*, Hillsdale College, Hillsdale MI, collection of primary sources for military history. Emphasis added.**
- **Lucius sounds like a person who needed little sleep.**
- **Differentiates between sleep that provides recovery from great mental exertion and long hours of wakefulness, and sleep between periods of idleness.**

The ‘Watch’ in Ancient Times*

- **As far back as Virgil and Homer, sleep was described as being divided into two periods during the night, separated by a period of wakefulness “sometimes called ‘the watch.’”**
- **Recent sleep research by Tom Wehr of the National Institute of Mental Health suggested that, given freedom from the pressures of work and allowed up to 14 hours to sleep overnight, people tend to sleep more than eight hours per night, *often including the middle waking period*.**

***Susan Brink (2000). Sleepless society. *US News and World Report*, 16 Oct, pp. 63-72.**

The ‘Watch’ in Medieval Times*

- **“Until the modern era, up to an hour or more of quiet wakefulness midway through the night interrupted the rest of most Western Europeans.”**
- **“Remaining abed, many persons also … reflected on the dreams that typically preceded waking from their ‘first sleep.’"**
- **“Not only were these visions unusually vivid, but their images would have intruded far less on conscious thought had sleepers not stirred until dawn.”**

The ‘Watch’ in Medieval Times*

- **“The historical implications … are enormous, especially in light of the significance … attached to dreams for their explanatory and predictive powers.”**
- **Suggests that “consolidated sleep, such as we today experience, is unnatural”**
- **Suggests that “segmented slumber afforded the unconscious an expanded avenue to the waking world that has remained closed for most of the Industrial Age.”**

A. Roger Ekirch (2001). Sleep We Have Lost: Pre-industrial Slumber in the British Isles. *American Historical Review*, 106(2).

The Military Watch

- **Tradition that divides the night into the first watch and the second watch**
- **The timing of these military watches may have corresponded loosely with the first and second sleeps**
- **The changing of the guard may have occurred during “the watch,” between normal sleep periods, when the present guard and the guard’s relief both tended to be awake**
- **Watchstanding on seagoing vessels took on a different pattern of timing more than 700 years ago, but there were other influences on work and sleep schedules at sea (Miller, 1999)**

Napoleon's View of Fatigue in Military Operations

- **1796: "You must not needlessly fatigue the troops." To the Armée d'Italie**
- **58th Maxim: "The first qualification of a soldier is fortitude under fatigue and privation. Courage is only the second." WE Cairnes, DG Chandler, ed. (1995). *The Military Maxims Of Napoleon*. Da Capo Press, 1901.**

The Early Days of Fatigue-Related Research

- **Mosso may have conducted the first systematic, generalizable study of muscular fatigue in 1884 and may have pioneered the finding of a physiological mediation of muscle fatigue in 1892.** Simonson E (1971). ***Physiology of Work Capacity and Fatigue***. Charles C. Thomas.
- **1890s: French balloon ascents and *La Pression Barometrique* (Paul Bert)**
- **1903: First powered flight at Kitty Hawk**
- **1907: US Army Signal Corps established an Aeronautical Division**

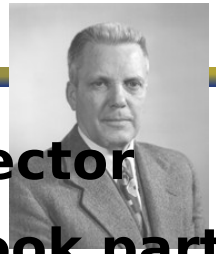
The Early Days of Fatigue-Related Research

- **1917: Theodore Lyster appointed as first chief surgeon of Aeronautical Division**
- **1918: Army Air Service Medical Research Laboratory, commanded by WH Wilmer, activated at Aeronautical General Supply Depot (Mitchel Field), Long Island NY**
- **1919: Louis Bauer relieved Wilmer and established the School for Flight Surgeons at Mitchel Field Lab**
- **1921: Mitchel Field Lab fire**
- **1922: Army Air Service School of Aviation Medicine (SAM) activated at Mitchel Field**

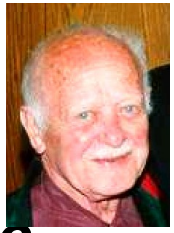
The Early Days of Fatigue-Related Research

- **1921: Muscio championed the idea of defining fatigue as a measurable, time-dependent change from before to after a period of performance.**
- **1926: the School of Aviation Medicine moved from Mitchel Field to Brooks Field**
- **1927: Harvard Fatigue Laboratory founded. L.J. Henderson, Elton Mayo: "the group psychology, the social problems, and the physiology of fatigue of normal man must be studied … to determine their interrelatedness and the effect upon work."**
- **Foundations of "expeditionary physiology" and "environmental physiology" laid by Per Scholander and Bruce Dill, respectively.**

Harvard Fatigue Lab, 1927-1947*



- **D. Bruce Dill:** Laboratory Director
- **Ashton Graybiel:** on staff; “took part in several Laboratory investigations into anoxia” as a research collaborator
- **John H. Talbott:** on staff 1927 to 1942; “member of the first high altitude and desert field studies, was responsible for the heat illness study at the Ohio steel mill, and was clinical investigator for the high altitude study of 1935.”
- **Charles A. Knehr:** on staff from 1937 to 1941
- **Ross McFarland:** Part of the Andean expedition of 1935; on staff in 1937
- **Steve Horvath and Sid Robinson:** doctoral students



*SM Horvath, EC Horvath (1973). *The Harvard Fatigue Laboratory: Its History and Contributions*. Prentice-Hall

The Early Days of Fatigue-Related Research

- **1931-1937: Bills pioneered the systematic study of mental fatigue in terms of mental "lapses"**
- **1931: Army AF School of Aviation Medicine moved from Brooks Field to Randolph Field**
- **1935: The U.S. Army Air Corps Physiological Research Unit was established at Wright Field under the command of Captain Harry G. Armstrong. The unit conducted the first studies of human performance under the special environmental conditions of flight (APA)**
- **1935: FAA established the Civil Aeromedical Institute**
- **1939: Navy established the School of Aviation Medicine at Pensacola**

Fatigue Lab's Andean Expedition of 1935*

- **Encamped at Quilcha, Chile, at 17,462 feet (5340 m), with research station in an ice cave at 20,078 feet (6140 m)**
- **Many symptoms could be attributed to altitude effects, including "shortness of breath on exertion and easy fatigability, … disturbed sleep and lassitude."**
- **McFarland and others extended these observations with studies of aircrew and passengers on high-altitude commercial flights in the days before aircraft cabin pressurization (McFarland, 1947).**
- **They noted obvious altitude acclimatization among aircrew members due to repeated, job-related exposure to high altitude.**

Emphasis added

Fatigue Lab's Mississippi Delta Heat Study of 1939*

- **Field workers walked at a constant metabolic rate of 1.8 liters O_2 consumption per minute**
- **During the last part of the walk, cardiac output decreased, heart rate increased and stroke volume fell off dramatically**
- **"The inability to maintain an adequate cardiac output in the face of a steadily increasing body temperature and inadequate evaporative cooling resulted in exhaustion of the subject and an inability to continue work."**

Emphasis added

National Research Council*

- **1939: Committee on Aviation Psychology supported Jack Jenkins and Alexander C. Williams, Jr., U. Md. that year to investigate psychophysiological "tension" as a determining factor of performance in flight training**
  - **Their use of a polygraph in flight may have represented the first time that pilot performance and physiology were measured together in the cockpit**
- **Frederic Lee chaired the Committee on Industrial Fatigue, which was set up to increase productivity in the face of long hours deemed necessary for war readiness.**

***Division 19, Military Psychology Division, American Psychological Association (December 2001), World Wide Web**

The Fatigue Lab in WWII*

- **“At Wright Field in 1940, Dill discovered a small room capable of attaining –40 deg C and with a large wind velocity.”**
  - **“He conducted “studies on the capability of nude men to tolerate these low temperatures … The principal investigator and, as was fairly usual, the first subject was Dill.”**
  - **“Fatigue laboratory personnel were on a continuous exchange through the early days of the war, and most of them were subjected to the same test at Wright Field.”**
- **Henderson foresaw the Laboratory’s “relevant function in research on the nutrition and climatic adaptation of the soldier in wartime…”**

The Fatigue Lab in WWII*

- **“Several members left for wartime duty, either as commissioned officers or as civilians assigned to military facilities, other stayed to contribute to and play essential roles in cooperative efforts with military establishments, and some joined the Laboratory for that purpose.”**
- **“Dill was commissioned in 1941 to work for six months [then, 5 years] at the Wright Field Aero Medical Laboratory, … under the command of Otis O. Benson, Jr., then Captain in the Medical Corps.”**
- **“Benson … had spent the preceding summer at the Fatigue Laboratory in preparation for taking command of the Wright Field laboratory.”**

The Fatigue Lab in WWII*

- **“Ashton Graybiel initiated physiological research at the U.S. Naval School at Pensacola”**
- **“[Steve] Horvath conducted research in cold and the special problems of Army tank crews at Fort Knox”**
- **“Charles Knehr served as personnel classification officer in the Air Corps.”**
- **“John Talbott was appointed to direct the Army’s new Climatic Laboratory at Lawrence, Mass.”**

The Fatigue Lab in WWII*

First-Generation Laboratories:	Investigators:
Army Climatic Stress Lab, Lawrence MA	JH Talbott, AC Barger
Bethesda Naval Medical Research Institute, MD	WV Consolazio, GC Pitts
Fort Knox Armored Medical Research Lab, KY	SM Horvath
Pensacola Navy School Aeromedical Lab, FL	A Graybiel
Wright Field Aero Medical Lab, Dayton OH	OO Benson Jr., DB Dill, FG Hall, JW Wilson, V Guillemin
Second- and Third-Generation Laboratories:	**Investigators:**
Army Chemical Corps Medical Research Lab, MD	DB Dill, A Abramson, E LeB Gray, P Robinson, JL Whittenberger
Army Medical Research & Nutrition Lab, Denver CO	CF Consolazio
Quartermaster Army Medical Nutrition Lab, Chicago IL	RE Johnson, CF Consolazio

Fatigue Lab's Study of Heat Acclimatization*

- **Early in WW II, investigated the ability of man to acclimatize to work in dry heat (40deg C and 23% relative humidity)**
- **"Two subjects whose walk was terminated at 85 minutes on the first day could walk easily for 270 [minutes] after acclimatization."**
- **Cardiovascular system and evaporative cooling mechanism are limiting factors contributing to physical fatigue during work in the heat**

Emphasis added

Fatigue Lab's Studies of Nutrition*

- **Effects of nutrition on physical fitness and work capacity**
- **Many results published in the open research literature, and many only in government technical reports used by the Army during and after WW II**
- **A manual prepared as a result of this work, describing methods for field evaluations of the nutritional level of men, still in use in 1973 in an updated version**

Army Aviation Psychology*

- **1940: John Flanagan set up a large aviation psychology program for the Army**
  - **Arthur Melton, Chief of the Department of Psychology, School of Aviation Medicine, Randolph Field; investigated use of psychomotor tests to predict aptitude for flying**
  - **Evolved into US Army Air Force Aviation Psych. Program**
  - **Labs at Mather AFB (Sacramento CA), Stead AFB (Reno NV), Williams AFB (Phoenix/Mesa AZ), Tinker AFB (Oklahoma City OK), Goodfellow AFB (San Angelo TX), Lowry AFB (Denver CO), Tyndall AFB (Panama City FL), and Lackland and Randolph AFBs (San Antonio TX). Broken up in 1958.**

***Stan Roscoe (1997). *The Adolescence of Engineering Psychology*. Human Factors and Ergonomics Society, Santa Monica CA.**

Post-WW II—Psychology Branch, Wright Field*

- 1945: The Aero Medical Laboratory at Wright Field near Dayton established a Psychology Branch
- Directed by Lt Col Paul Fitts; included Major Walter F. Grether and 1st Lt Wilse B. (Bernie) Webb among 21 officers, 25 enlisted and 10 civilians
- [Webb later created a pioneering sleep research laboratory at U. Florida]
- 1949: Fitts succeeded as branch chief by Grether

Post-WW II—Navy Human Engineering and Research*

- **1945: Navy established human engineering program under Franklin V. Taylor at Naval Research Laboratory in Washington DC**
- **Established their Special Devices Center at Sands Point, Port Washington, Long Island NY.**
- **Leonard C. Mead headed the Sands Point Human Engineering Division**
  - **Monitored a 20-year ONR contract with the Aviation Psychology Laboratory at U. Illinois**
  - **1946: The APL was started by Alexander Williams, who had "served both as a selection and training psychologist and as a Naval aviator."**

Post-WW II--Ohio State University*

- **1946: Melton left military service to return to academia at Ohio State**
  - **Promoted research and initiated an extension graduate program at Wright Field**
  - **Brought his Air Force and Division 19 colleague, Paul M. Fitts, to Ohio State**
- **Before Fitts arrived at Ohio State, the Air Force asked Melton to organize a psychological research unit in San Antonio, Texas**
- **Melton took a leave of absence from Ohio State to establish what eventually became the Air Force Personnel Training and Research Center, where he remained as Technical Director**

Post-WW II—Navy Human Engineering and Research*

- **1946: A Human Engineering Division was formed under Arnold Small at the Naval Electronics Laboratory on Point Loma in San Diego CA**
- **The same year, “Captain Jack Dunlap separated from the US Navy, joined The Psychological Corporation in New York City, and immediately established a biomechanics division.”**
- **One of Dunlap’s initial recruits was Martin A. Tolcott. This group eventually broke off to form Dunlap and Associates.**
- **[Marty Tolcott moved later to ONR and sponsored a number of investigations of human vigilance performance by Bob Mackie at HFR.]**

Post-WW II—Considerations of Fatigue

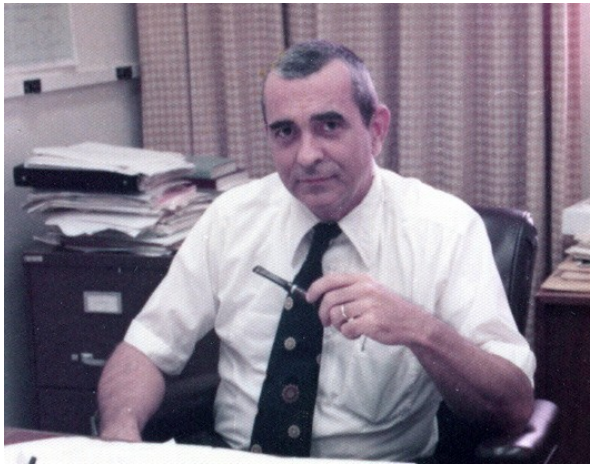
- **The Cambridge Cockpit Stiudies (Bartlett, 1942; Davis, 1948; Drew, 1940) had shown Muscio's 1921 idea of defining fatigue as a measurable, time-dependent change from before to after a period of performance to be applicable to simulated flying performance**
- **1947: Bartley and Chute provided some integration of thought when they suggested that, in addition to using the term fatigue to describe subjective (personalisitc, experiential) perceptions, that the term "impairment" be used to refer to work deterioration measurable at the tissue level, and that the measurement of one of these phenomena revealed little about the other.**

Post-WW II—Considerations of Fatigue

- **1946: Interestingly, the findings of the Cambridge Cockpit Studies were not included in Ross McFarland's extensive discussion of crew factors that should be considered in aircraft design.**
- **1947: Conversely, Bartley and Chute did not use aircrew fatigue as an example of fatigue research nor as an example of an operational fatigue problem in their book.**
- **One conclusion that may be drawn from these absences is that aircrew fatigue was not considered to be a serious problem in the mid-1940s.**
- **1946: However, the Vitale Committee emphasized subjective perceptions of fatigue in its report to the Civil Aeronautical Administration (Derickson, 19xx).**

Post-WW II--Ohio State University*

- **1949: Paul Fitts opened the Laboratory of Aviation Psychology at Ohio State University**
- **1952: Bryce O. Hartman, Charles W. Simon and Oscar Adams received the first doctorates awarded by that Laboratory**



- **Hartman then initiated "his long career at the School of Aviation Medicine in San Antonio" in Clinical Sciences (SAM/NG).**
- **Simon went to Rand Corporation in Santa Monica CA; Adams went to Lockheed-Georgia in Marietta GA.**
- **1958: Fitts joined Melton at the University of Michigan and passed away after a heart attack at the age of 53. Fitts was succeeded at Ohio State by George Briggs.**

Post-WW II—Considerations of Fatigue

- In a research response to the 1946 Vitale report, Hartman and Fitts (1950) assessed air traffic controller “alertness”
- They viewed alertness, defined as responsiveness to stimuli, as an inverse function of fatigue, a function that could be quantified more easily than fatigue
- See also, Hartman and Fitts (1955); this latter publication was relatively coincident with the first publication of Fitts’ Law in 1954

Human Performance Research at USAFSAM

- **1959: AF School of Aviation Medicine moved to Brooks and became part of the new Aerospace Medical Center (AMC), Hq at Brooks AFB. In Bldg 140, then Bldg 110 when it was built, and then Bldg 170, where it remains.**
- **A major objective of all research at SAM in 1959 was the Manned Orbiting Laboratory (MOL; a mock up resided in Bldg 170 through about 1982), and man in the space environment. Hence, Billy Welch's Environmental Sciences Division (SAM/VN).**
- **Hartman worked closely with the original seven astronauts; he later moved to VN to become a Branch Chief of SAM/VNB, the present WFC.**

Human Performance Research at USAFSAM

- **1961: SAM became part of the new Aerospace Medical Division (AMD), Hq at Brooks AFB, for next 30 years**
- **1969-71: Bill Storm on an NRC post-doc at the 6571st Aeromedical Research Lab, Holloman AFB, NM; Storm met Hartman, who was conducting studies at the 6571st; collaboration on sleep/work-schedule research using primate models.**
- **1971: The AMD closed the 6571st Lab (AF gets out of the monkey business); Hartman hired Storm to join him at USAFSAM**
  - **One of Storm's research mentors at 6571st was Dr Vern Pegram, who moved to Alabama where he mentored Lynn and John Caldwell.**

Human Performance Research at USAFSAM

- **1980: Hartman became SAM/VN Division Chief. John Courtright arrived from W-P to become SAM/VNB Branch Chief; departed later for non-government work in Albuquerque NM. Jay Miller arrived at VNB; departed for Edwards AFB in 1987 to become HFE Branch Chief for the Test Wing.**
- **1982-1988: Crew Performance Function of VNB; Bill Storm as Function Chief**
- **1982: Doug Eddy joined as a contractor; enhanced program by injecting Cognitive Psychology**
- **1983: Sam Schiflett arrived; reassigned to AFRL/HEA in 1997; retired in 2002**
- **1988: Jon French arrived in VNB; RIFed in 1999 and began non-government work in Orlando FL**

Human Performance Research at USAFSAM

- **1989: Mike Rea arrived; conducted basic research on circadian rhythms in BRAIN (Bldgs 1192 & 1179); RIFed in 1999 and moved to U. Houston**
- **19xx: Rod Hughes arrived; designed and built sleep lab at Bldg 1192; departed in 19xx to Harvard and then Cephalon**

Human Performance Research at Armstrong Lab

- **1991: The research functions of SAM became part of the new Armstrong Laboratory (AL), Hq at Brooks AFB, for 6 years; SAM/VNB became AL/CFTO**
  - **The Armstrong Aeromedical Research Lab at Wright-Patt, including the old Fitts Lab, and the AF Human Resources Lab at Brooks also become part of AL**
- **Reorganization created the Aerospace Research Branch; Russ Burton as Branch Chief, then Bill Storm**
- **1991: Hartman returned to SAM/NG as an Emeritus when Armstrong Lab (AL) was born. Bryce retired in 19xx and passed away in 19xx.**

Human Performance Research at AF Research Lab, Brooks

- Aerospace Research Branch subdivided into physiology and behavioral branches, with Bill Storm as Chief of the behavioral Branch to 1996, and then 1997 to 2002
- 1997: AL became the Human Effectiveness Directorate (HE) of the new AF Research Laboratory, Hq at Wright-Patterson AFB. AL/CFTO became AFRL/HEPM and included the fatigue and circadian rhythm R&D group and the environmental physiology groups.
- 1999: Fatigue R&D program halted due to research budget cuts; all CFTO Civil Service personnel RIFed except Bill Storm

Human Fatigue and Performance Research at AF Research Lab

- **2000: Fatigue R&D program restored. Jay Miller returned from non-government work. Fatigue function named Warfighter Fatigue Countermeasures R&D Program (WFC) within HEPM. Chronobiology and Sleep Lab (CASL) established in Bldg 1192.**
- **2002: Maj Brandon Doan became Branch Chief; John and Lynn Caldwell arrived in HEPM from AAMRL, Ft Rucker; Brooks AFB changed to Brooks City-Base**
- **2003: HEPM became solely dedicated to fatigue and human performance R&D; re-named Warfighter Fatigue Countermeasures Branch**